Monitoring and Management of Visitor Flows in Recreational and Protected Areas
Conference Proceedings ed by A. Arnberger, C. Brandeburg, A. Muhar 2002, pages 211-217

A Spatial Model of Overnight Visitor Behavior in a Wilderness Area in Eastern Sierra Nevada

John Lynch

School of Renewable Natural Resources
University of Arizona
Tucson, Arizona, USA

Abstract: This paper documents an attempt to simulate spatially the behavior of a group of sampled overnight visitors in a dispersed recreation setting – the Humphrey's Basin region of the John Muir Wilderness in the eastern Sierra Nevada Mountains. This study utilizes spatial data depicting the behavior of backcountry visitors in Humphrey's Basin to formulate a model based on cost surface techniques in a geographic information system (GIS) to develop a measure of visitor effort expenditure as a way of describing factors influencing spatial distribution of camping behavior. This hiking effort index model (HEI) measures the accumulative cost hikers expended to traverse varying distances between campsite locations in the study area. The cost grid input for the HEI model consisted of a) a slope factor derived from digital elevation models (DEM), b) the measured hiking times of backpackers at various slopes, and c) the relative cost of traveling either on or off trail. The model measures relative travel cost in units of hiking minutes. The model was tested using a subsample of the actual spatial data of visitor behavior not used in the running of the HEI model. Results indicate that the HEI model does accurately simulate the spatial distribution of visitors. This study thus suggests that human behavior in a dispersed recreation setting can be successfully modeled as well as pointing to ways of further improving simulation techniques
.

INTRODUCTION

Social scientists recognize that human spatial patterns are more than just background to or expressions of social action. They understand that spatial patterns are instrumental to the formation and reproduction of human behavior (Penn and Dalton, 1994). Yet, little research exists that describes how people distribute themselves within recreation systems (Wang and Manning, 1999). This means that significant aspects of the character of encounters, conflicts, experience opportunities and benefits in recreation are not well understood (Gimblett et al., 2001).

Much of the research about recreation in wildernesses and other protected areas during the last forty years has concentrated on adapting the concept of carrying capacity to recreation use (Stokowski, 2000). The carrying capacity work, and its theoretical complement, normative theory, have produced useful findings (Shelby et al., 1996; Cole and Hammitt, 2000). Yet, researchers have debated the applicability of the carrying capacity concept to human recreation issues for years (Wagar, 1974; Manning and Lime, 2000).

One critical deficiency of human dimensions research is the lack of data that captures actual patterns of human use of natural resources (Ewert, 1996). Managers in heavily used wilderness areas have been found to rely for the most part on personal opinion in their decision-making (Cole, et al., 1997). Basic information on human use in protected areas is patchy (Manning, 2000). The low frequency of monitoring of human use belies its importance to wilderness management (McClaran and Cole, 1993). Recreation use is still inadequately measured and described (Watson, et al. 2000). Without better data better models of human use patterns can't be produced (Machlis and McKendry, 1996). The data that needs collecting should be of the type, and only of the type, that is actually needed by managers and other decision makers (Williams, 1998).

A stated objective of new recreation models is to empower land managers to make better-informed decisions while reducing the negative consequences of policy decisions. Models have been defined as simplified copies of complex entities or systems, copies that allow otherwise impossible or impractical study of the most important aspects of those systems (Gilbert and Troitzch, 1999). In the case of a recreation model of a wilderness area, an effective spatial/temporal model of a backcountry area could enable managers to comprehensively map human use and preview the implementation of policies and their consequences (Gimblett et al. 2000). In contrast to human use pattern models that are derived from spatial/temporal data, policy decisions based solely on experience and intuition and tested through trial and error tend to be costly, time-consuming and harmful to visitor relations (Shechter and Lucas, 1978).

A spatial model is particularly appropriate in a recreation context because how visitors perceive impacts and the quality of their experience is predicated to a significant degree upon where exactly encounters and conflicts occur. A significant problem in simulating human use patterns is the complexity of human behavior. An outstanding feature of models such as the wilderness use simulation model (WUSM) was their capacity to handle complexity. Therefore, the objectives of this study were to simulate the character of human behavior by isolating some of the contributing factors into that behavior.

STUDY AREA

This study was conducted in the Humphrey's Basin area of the John Muir Wilderness. Humphrey's Basin is an alpine lakes basin located in the Inyo and Sierra National Forests in California. It is located about 32 km. west of the town of Bishop, which is approximately 480 km. east-southeast of San Francisco and 440 km. north of Los Angeles. For the purposes of this study, Humphrey's Basin is defined by Lake Italy to the north, the Pacific Crest Trail to the west, the Kings Canyon National Park boundary along the Glacier Divide to the south, and by North Lake to the east. This defined area is 145,763 acres or 590 sq. km. Practically speaking though, the actual boundary of the study area was defined by the map provided for participants upon which they recorded their information. Any visitor behavior that occurred within the confines of the map provided as part of the data collection was deemed to have taken place within the study area itself.

Humphrey's Basin is ideally suited for studying complex recreation behavior. Being a large wilderness area it offers varied settings in which visitors can travel on- and off-trail, and can choose destinations from innumerable suitable locations. Although permits are required by the Forest Service for overnight use in the John Muir Wilderness, backpackers are free to camp wherever they please, as long as they camp the stipulated distance away from water sources. The basin is accessible to and used by dayhikers, overnight backpackers, packstock trips (trips using pack animals -- horses and mules) and guided mountaineering trips.

UNIVERSITY OF ARIZONA STUDY

The data used to build the HEI model was collected as part of a larger study conducted cooperatively by the Forest Service and the University of Arizona. The Forest Service contracted with the university for two seasons of data collection on backpacker, packstock outfitter and mountain guide use in nine study areas during one season and in three of the same areas the following season. Humphrey's Basin was one of those areas studied both years. The Forest Service has used data drawn from the study in the completion of a general management plan for the John Muir and Ansel Adams wilderness areas. Their use of the data is not related to this study in any way.

Data from the Arizona/Forest Service study were collected during two seasons, 1999 and 2000, of permitted overnight backcountry use in the nine study areas. Dayhikers were not asked to participate. Data was collected for a total of eight months spread over the two seasons. In both study seasons, data collection forms were first distributed on or just before the fourth of July and were continuously available until the end of the backcountry season. The end of the season varies yearly, depending on the arrival of snow. In 1999 and 2000, season's end occurred sometime in late October.

Data was collected through the use of a type of trip diary or, as they were referred to for the purpose of this study, trip reports. The traditional recreation data collection mechanisms, interviews and surveys, were not used for this study. Those methodologies don't capture situational effects well, while visitors may have no conscious strategy in their spatial behavior and might not be able to articulate it even if they did (Stewart, 1998; Gilbert and Troitzch, 1999).

Some research indicates that observing a sample of trails and trailheads on sample days produces optimal data on visitor behavior. This method wasn't feasible in this study, given the cost that would be involved and the size of the study areas. Using self-administered methods, as in the case of mandatory permit systems, generally has been found to produce adequate results (Lucas and Kovalicky, 1981).

Each trip report consisted of three sections. The first solicited general information about visitors and their trips. This information included what trailhead each party left from. Section two was a series of questions regarding visitor satisfaction with different features of the wilderness experience. The section's data had no bearing on the development of the spatial models that concern this discussion.

The final section of the trip report asked wilderness visitors to record where they went on their trip, whom they encountered there, and how long they spent at each campsite. Each separate study area contained a different map. Like the satisfaction information, the encounter information isn't relevant to this model. The data that does concern this model was where visitors camped and for how long. Visitors denoted the location of each camping incident by marking a dot on a map included in the trip reports. Alongside each dot visitors wrote on the map the night or nights they spent at that campsite. Only camping occurrences that took place in Humphrey's Basin were counted and analyzed for this model. Accordingly, information from visitors who began their trips outside of the basin but spent part of their stay within the area was included in this study.

Trip reports were distributed to visitors through a number of outlets. Trip report stations that allowed the reports to be self-administered by visitors were set up at feeder trailheads that provide access to Humphrey's Basin. In 2000, the Forest Service sent trip reports to all visitors who received their permit by mail. This wasn't possible in 1999. The trip reports came with a self-addressed postage-paid envelope. Visitors were instructed to take a trip report with them during their visit, complete it as they went along, and then seal the finished report in the envelope and drop it in the mail. Reports were mailed to the University of Arizona in Tucson, AZ.

The data collection methods used in this study acted as a limitation to the precision of the eventual modeling results. The backcountry visitors who participated in this study were not selected in a strictly random manner. Not all visitors had an equal chance of receiving a trip report and there was some degree of bias in what portion of the population of visitors returned completed trip reports. An overwhelming majority of returned trip reports came from people who took them at trailheads. Only an insignificant portion came from those administered through the other distribution methods. Therefore the sample used in this study can't be said to be strictly representative of visitors to Humphrey's Basin. Also, visitor use studies have concluded that visitors often misreport where they go in the backcountry. Ideally, observers would record visitor behavior (Cole et al. 1997).

MEASURING DISTANCE BY A COST SURFACE

Once the data was collected from the wilderness study area, the next step was to find the principle on which to build the model. Rossmo argues that the most fundamental analytic device in geography is the nearness principle, also known as the least-effort principle. Rossmo defines the least-effort principle as: given his choice, a person will select a route that requires the least expenditure of effort. This suggests that all other factors being equal, hikers will always chose the closest destination (Rossmo, 2000). Tests of animal behavior demonstrates that animals do use least-cost pathways (Ganskopp and Johnson, 1999). But how does one define closest? Does it involve more than just distance? Rossmo argues that the perception of distance is influenced by the relative attractiveness of destinations, the number and types of barriers along the route, the traveler's familiarity with the route, the actual physical distance, and the attractiveness of the route.

The nature of the data collected in the Sierra excluded consideration of all but two of the influences Rossmo cites. The data from Humphrey's Basin meant a spatial model would have to be constructed from the distance traveled by hikers and the barriers they faced on their trips. DeMers states that the way to show the functional distance covered by travelers is to calculate an impedance value for their trip. This impedance value is the accumulative cost incurred as distance is crossed (Demers, 1997). Accumulative cost assigns a distance value to a route that counts some associated measurement besides feet or meters. For example, the accumulative cost of the flow of water runoff might measure impedance by the degree of slope of the terrain and the density of vegetation screens along the route. Thus, for hikers in the Sierra, the accumulative cost of hiking would be the total expenditure of effort, however that is measured, they expend to negotiate the landscape.

Raster-based GIS calculate the accumulative cost of a route in the form of a cost surface. To produce a cost surface, which is represented by a tessellated grid, one selects a starting point, or source cell, which has an accumulated cost of zero. As the GIS window moves across the cells adjoining the source cell, the GIS adds the cost of traversing each cell to the total already counted. For example, crossing a cell adjacent to the source that has an associated cost of 1 would leave the journey with an accumulated cost of 1. If the next cell crossed has an associated cost of 2, the accumulated cost to that point of the route would be 3, and so on until the terminus is reached. So, a cost surface is the representation of the value associated with the difficulty of traveling to each point on the surface from the starting point. Accordingly, locations on the cost surface that are remote from the source cell will have much greater values than cells proximate to the starting point.

ASSIGNMENT OF ROUTE COST

The topography of Humphrey's Basin was represented by a digital elevation model (DEM). This DEM was constructed by reformatting eight DEMs into grids using the ArcInfo GIS and then combining them. The eight 1:24,000-scale (7.5 minute) digital elevation models (DEMs) used to represent the study area were obtained from the US Geological Survey. The DEMs used in this study were of Florence Lake, Mt. Darwin, Mt. Henry, Mt. Hilgard, Mt. Thompson, Mt. Tom, Tungsten Hills and Ward Mountain. These DEMs were combined by the *mosiac* command in ArcInfo. GIS allow reprocessing of DEMs into maps representing various features latent in topography. One determinant of cost in the HEI model would be the degree of slope of the cells hikers traversed in the cost surface. ArcInfo was used to reclassify the combined DEM into a grid representing slope values for the area.

The degree of slope had to be translated into some unit of measurement to depict the relative cost of each cell. Time was chosen as the measurement unit. Wagtendonk and Benedict conducted a study of travel time variation among backpackers on trails of different slope in Yosemite National Park (Wagtendonk and Benedict, 1980). They timed backpacking parties as they hiked a mile on a trail of gentle rise (.75%), a trail of moderate rise (5.0%), and a trail of severe rise (12.5%). They considered trails of this slope to be the only pertinent routes in Yosemite. They did extrapolate these measurements later to obtain travel times for trails of steeper slopes. A c*on* state- ment in ArcInfo was used to reclassify the slope grid using the travel times in the Yosemite study and thus obtain a cost grid of hiking times for each cell in the study area. Cells having a gentle slope were assigned a value of .019, those with a moderate slope were assigned a value of .023, and those cells with steep slopes were assigned a value of .025. These values were reached by taking the averaged slope class values that represented number of minutes needed to hike a mile. These values were then converted for travel times needed to cross a one-meter cell.

Hiking cross-country is almost always more difficult than doing so on established trails. To account for this increased difficulty for hiking cross-country, each cell in the study not associated with a hiking trail in Humphrey's Basin was assigned double the impedance value. This doubling of difficulty values was chosen to reflect the increase in difficulty that hiking off-trail involves without inordinately skewing the influence of this factor on the model's results as a whole. Therefore the range of values in the cost grid to be used in the production of the cost surface were from .019 minutes for cells on a gentle slope and trail to .051 minutes for cells on a severe slope without a trail.

RUNNING THE HEI MODEL

The cost spent in time hiking was then calculated for each applicable segment of travel between campsites used during backcountry visits in Humphrey's Basin. This derivation of hiking effort times, which does not correspond to the actual time elapsed between campsites, but rather the cost of travel as expressed in hiking times, was done in two sections: first nights and last nights. The first night section comprised segments where the travel was between the Piute Pass trailhead and a first night's camping. A grid was made with just the Piute Pass trailhead. This source grid and the cost grid were the inputs to the c*ostdistance* function in ArcInfo. Only first nights of trips that originated at the Piute Pass trailhead were used. There were 229 reported first nights of this type in the database. Of these, 10% were not used in the model. These 23 would be used to test the model later. The 10% figure was chosen because it provided the best compromise between the conflicting needs to have a large enough sample to run the model and still have a sufficiently large reserve sample set aside to test the model with.

Section two, last nights, used all final nights of any trip that terminated at the Piute Pass trailhead. The source grid was again the Piute Pass grid. Any camping incident was used as long as it was the last night of a trip and it ended at this trailhead. Also, the concluding night's campsites of trips beginning outside the study area were included in this section as long as the final night occurred within Humphrey's Basin and the trip ended at the Piute Pass trailhead. There were 233 total nights in this section. Setting aside 10% for model verification, left 210 for running the model.

TESTING THE HEI MODEL

To test the accuracy of the hiking effort index model, a cost surface with the Piute Pass trailhead as the source point was produced. This surface was then reclassified into zones corresponding to the 20%, 40%, 60%, 80% and 100% percentiles of the First Night and Last Night sections. The procedure for testing was to overlay the 10% sample of camping incidents set aside from the two sections on the zones created from the model. If the model has any validity the 10% subset, randomly chosen through the SPSS statistics software, would fall within the zones in the same percentages as occurred in the larger set. For instance, for first nights, 20% of campsites had a HEI figure of 88.8 or less. Therefore one would expect 20% of the 10% subsample or 4.6 incidents to fall within that first zone. Likewise, 40% of the 23 or 9 should fall within the zone delimited by zone two, which had a zone boundary denoted by the HEI number of 124.4.

RETURN RATES FOR TRIP REPORTS

521 trip reports were returned from the Humphrey's Basin study area, 324 from 1999 and 197 from 2000. There are several ways to judge the success of this return. One way is to compare the number of returned reports with the number of reports actually put into the hands of overnight visitors. Because of the logistical difficulties of administering this study, such a comparison can only be broadly estimated. Given the numerous distribution points – pack stations, mountaineering centers, ranger stations, visitor centers, etc. – and the length of the study periods, no census of the actual number of trip reports given to visitors has been conducted. A general estimate is that between 6,000-7,000 were handed out for all areas in 1999. 1455 trip reports were returned from all areas that same year. No figures are available for Humphrey's Basin alone. For 2000, around 2,000 reports were probably handed out in the three areas. Of those 397 total were mailed back. So, 1999 had a return rate (using 6,500 as the number given out) of 22.3%. 2000 had a rate of 19.8%. This is a rough measure of the percentage of permitted parties who knew of the study and participated.

Another way of judging the participation rate is to compare the number of returned reports with the number of permits issued. This analysis can be done on the study areas separately. 1007 permits were issued for Humphrey's Basin trailheads in 1999. That is a return rate of 32.2%. This was the second highest rate return rate of the nine study areas. 644 permits were issued for use in the Mono Creek study area, which is located directly to the north of Humphrey's Basin. 139 trip reports were returned from there, a 44.7% rate. The lowest return rate, 16.1%, was in the Rush Creek area. 323 permits were issued for there and 52 trip reports returned. The percentage of reports returned against permits issued for all nine areas was 25.1%, 1371 against 5467 (one study area had no figures for permits issued). No figures were available for permits issued for 2000. This analysis begs the question of whether in this kind of study returns rates are of the same significance as they are in studies of visitor satisfaction. In those traditional recreation research studies consensus on the quality of experience is sought after. This study seeks to uncover use patterns, and for that there is no precedence established for how much data is needed to accurately establish those patterns.

RESULTS OF THE HEI MODEL

The presentation of the model results is done for all results, first nights, and last nights, as defined above. The table of the frequency statistics of the hiking time segments lists the results of the HEI analysis (table 1). The mean figure of 209.2 for all segments represents the cost in minutes of hiking effort that sampled backpackers expended on the average segment for all trips included in this survey. Histograms for all results and each of the two sections of analysis graphically present the distribution of hiking times (figure 1).

Segments	All	First	Last
n	460	228	232
Mean	209.20	178.57	239.31
Median	199.01	138.79	233.56
s	107.61	100.61	105.96
Minimum	4.74	4.74	22.24
Maximum	662.54	457.92	662.54
Range	657.79	453.18	640.30
20th percentile	116.49	88.80	135.18
40th percentile	179.82	124.44	202.46
60th percentile	231.22	188.19	265.10
80th percentile	295.85	278.96	302.50

Table 1: Results of HEI model, in minutes of hiking effort.

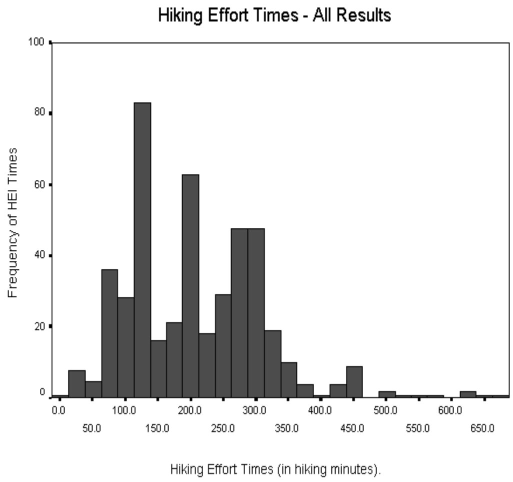

Figure 1: Histogram of hiking effort times for all segments run in the HEI model, n = 460.

TEST RESULTS OF HTI MODEL

The models of first and last nights both performed well. All 23 values of the test sample for both models fell within the study zones. As a whole, the first night model slightly underestimated the values, while the last night section slightly overestimated the values. For the 20th percentile, first nights were 35% under the expected value. Last nights were 35% over. First nights were within 2.2% of the expected value at the 40th percentile. Last nights were 23.3% over there. At the 60th percentile, first night values came within 1.4%. Last nights improved to being only 8% over the value. First nights stalled at the 80th percentile, and fell to being 24% under. Last nights held steady at 7.4%, this time being under. On average, the first nights section was 12.5% under the expected value. The mean of the discrepancy figure for last nights was 14.7%. The average accuracy for both sections was therefore 13.6% within the expected value. Chi-square tests on both sets of results confirm the accuracy of the model. With 4 degrees of freedom, the 95% chi-square statistic is 9.488. If the first and last nights sections were accurate one would expect to get chi-square results below 9.488. The first nights chi-square result was 1.609. The last nights result was 2.314.

DISCUSSION

The results of the hiking time analysis were not normally distributed. Both the first nights and last nights sections evidence multi-modal distributions. Both sections are positively skewed as well. Due to the presence of an obviously anomalous outlier, the range of all the results was inflated. This outlier, the maximum value of all results, was from the first nights section and represented a result so large that it was almost definitely the product of an error. Removing that value from the database reduces the range of results by 160 minutes of hiking time. Still there was great variance in the times recorded.

Removing the outlying values from the high end and some from the very low end in each section produces much more tightly grouped results. Once this is done it's clear that most segments took between 75 and 325 minutes of hiking time. The most frequently recorded times were 125 minutes and 200 minutes. The last nights had a larger corrected range than did the first nights. Both the last nights and the first nights had strong multi-modal distributions. Though there was a range of values in the percentiles listed in the table of results, that range wasn't that great. This supports the findings that there was a strong tendency of the results to cohere around the mean values. Not surprisingly the values for each of the percentiles grew larger as nights got later in the represented trips.

Despite the presumed diversity in personality types, levels of experience, goals and expectations of visitors to the study area, the hiking effort index results reveal some significant trends about hiking behavior taking place there. As the frequency statistics show, an average hiking segment in Humphrey's Basin took about 3 ½ hours of hiking time. The bias of the results to the positive side indicates that there are some hikers who, for at least part of their visit, hike for a much longer time than the average. This was to be expected. Still, contrary to expectations, these extreme hikers represented a relatively small percentage of the entire population of backcountry visitors. First night hikes, those from the trailhead to the first campsite, on average were the shorter of the two sections. Last nights were on average more than an hour of hiking effort longer. One can infer that visitors covered less ground early in their trips, increased distances as they went along, and did their longest hikes to return to the trailhead from their last campsite.

The spatial significance of the distributions of hiking times in all sections was marked. Most important is that these distributions show that campers preferred some areas to others, and that that preference had a very definite spatial aspect. The peaks in the histograms of hiking times correspond to those areas in Humphrey's Basin where visitors camped most often. For the results from all incidents, the most popular areas were those that correspond spatially to the hiking times of first, 125 minutes, and second, 200 minutes. The third most popular locations are those that correspond spatially to the hiking times grouped from 250 minutes to 300 minutes.

Another revealing occurrence is that the contrast of these popular times from the times next to them is so great. The 120-minute section in the histogram of all results had a frequency of 84. The sections on either side of it had frequencies of only 16 and 28. That means the 120-minute time, and destination, were much, much more frequented than those right next to it.

Thus, visitors repeatedly chose to camp at destinations that corresponded to very specific and narrow hiking times, and chose to pass over areas that were just around it. Thus the model demonstrated a very fine level of resolution to the spatial aspects of visitor behavior in the study area.

CONCLUSION

The results of this study strongly suggest that accurate spatial modeling of human behavior in dispersed recreation settings is possible. Limitations of the data collection methodology notwithstanding, the HEI model accurately simulated where backcountry visitors would camp. Additionally, the model characterized the differences in hiking behavior between the different portions of visitor trips. These attributes of the HEI model could assist recreation managers in understanding the spatial and temporal aspects of use in their protected areas. All human hiking behavior is a combination of "push and pull" influences, i.e. effort and attraction. This model concentrated on the "push" factors. Further study should entail modeling the complementary facets of the relative influence of landscape attractions – the "pull" of prime camping locations, scenic vistas and peaks for climbers – on visitor distribution.

REFERENCES

Cole, D. N., and W. E. Hammitt. "Wilderness Management Dilemmas: Fertile Ground for Wilderness Management Research." In *Proceedings of Wilderness Science in a Time of Change Conference, Vol. 1: Changing Perspectives and Future Directions,* held May 23-27, 1999 in Missoula, MT, compiled by D. N. Cole, S. F. McCool, W. Freimund, and J. O'Loughlin, 58-63. Ogden, UT. USDA Forest Service, Rocky Mountain Research Station, RMRS-P-15-Vol. 1, September, 2000.

Cole, D. N., A. E. Watson, T. E. Hall, and D. R. Spildie. "High-Use Destinations in Wilderness: Social and Biophysical Impacts, Visitor Responses and Management of Options". Ogden, UT: USDA Forest Service, Intermountain Research Station, Research Paper, INT-RP-496, October, 1997.

DeMers, M. N. *Fundamentals of Geographic Information Systems.* New York: John Wiley and Sons, 1997.

Ewert, A. W., "Human Dimensions Research and Natural Resource Management." In *Natural Resource Management: The Human Dimension,* edited by A. E. Ewert, 5-12. Boulder: Westview Press, 1996.

Ganskopp, D., R. Cruz, and D. E. Johnson. "Leas-effort pathways?: a GIS analysis of livestock trails in rugged terrain." *App. Anim. Beh. Scien.* **68** (2000): 179-190.

Gilbert, N., and K. G. Troitzch. *Simulation for the Social Scientist.* Buckingham: Open University Press, 1999.

Gimblett, H. R., ed. "Integrating GIS and Agent-Based Technologies for Modeling and Simulating Social and Ecological Phenomena." In *Integrating Geographic Information Systems and Agent-Based Modeling Techniques,* 1-20. London: Oxford University Press, 2000.

Gimblett, H. R., R. M. Itami, and M. T. Richards. "Simulating Wildland Recreation Use and Conflicting Spatial Interactions Using Rule-Driven Intelligent Agents." In *Integrating Geographic Information Systems and Agent-Based Modeling Techniques,* edited by H. R. Gimblett, 211-243. London: Oxford University Press, 2000.

Gimblett, H. R., T. C. Daniel, and M. J. Meitner. "An Individual-Based Modeling Approach to Simulating Recreation Use in Wilderness Settings." In *Proceedings of Wilderness Science in a Time of Change Conference, Vol 4: Wilderness Visitors,* *Experiences, and Visitor Management,* held May 23-27, 1999 in Missoula, MT, compiled by D. N. Cole, S. F. McCool, W. T. Borrie, and J. O'Loughlin, 99-106. Ogden, UT. USDA Forest Service, Rocky Mountain Research Station, RMRS-P-15-Vol. 4, September, 2000.

Lucas, R. C., and T. J. Kovalicky. "Self-Issued Wilderness Permits as a Use Management System." USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Paper, INT-270, 1981.

McClaran, M. P., and D. N. Cole. "Packstock in Wilderness: Use, Impacts, Monitoring, and Management." USDA Forest Service, Intermountain Research Station, General Technical Report, INT-301, September 1993.

Machlis, G. E., and J. E. McKendry. "Maps and Models for Natural Resource Management: Powerful Tools." In *Natural Resource Management: The Human Dimension,* edited by A. E. Ewert, 195-213. Boulder: Westview Press, 1996.

Manning, R. E. "Coming of Age: History and Trends in Outdoor Recreation Research." In *Trends in Outdoor Recreation, Leisure and Tourism,* edited by W. C. Gartner and D. W. Lime, 121-130. Wallingford: CABI Publishing, 2000.

Manning, R. E., and D. W. Lime. "Defining and Managing the Quality of Wilderness Recreation Experiences." In *Proceedings of Wilderness Science in a Time of Change Conference, Vol 4: Wilderness Visitors, Experiences, and Visitor Management,* held May 23-27, 1999 in Missoula, MT, compiled by D. N. Cole, S. F. McCool, W. T. Borrie, and J. O'Loughlin, 13-52. Ogden, UT. USDA Forest Service, Rocky Mountain Research Station, RMRS-P-15-Vol. 4, September 2000.

Penn, A. and N. Dalton. "The Architecture of Society: Stochastic Simulation of Urban Movement." In *Simulating Societies: The Computer Simulation of Social Phenomena,* 85-126. London: UCL Press, 1994.

Roggenbuck, J. W., D. R. Williams, S. P. Bange, and D. J. Dean. "River Float Trip Encounter Norms: Questioning the Use of the Social Norms Concept." *Journ. of Leis. Res.* **23** **(2)** (1991): 133-153.

Rossmo, D. K. *Geographic Profiling.* Boca Raton: CRC Press, 2000.

Shechter, M., and R. C. Lucas. *Simulation of Recreation Use for Park and Wilderness Management.* Baltimore: Johns Hopkins University Press, 1978.

Shelby, B., J. J. Vaske, and M. P. Donnelly. "Norms, Standards and Natural Resources." *Leis. Scien.* **18** (1996): 103-123.

Stankey, G. H. "Visitor Perception of Wilderness Recreation." USDA Forest Service, Research Paper, INT-142, November 1973.

Stankey, G. H., and S. F. McCool. "Carrying Capacity in Recreational Settings: Evolution, Appraisal, and Application." *Leis. Scien.* **6** **(4)** (1984): 453-474.

Stokowski, P. A. "Assessing Social Impacts of Resource-Based Recreation Tourism." In *Trends in Outdoor Recreation, Leisure and Tourism,* edited by W. C. Gartner and D. W. Lime, 265-274. Wallingford: CABI Publishing, 2000.

Wagar, J. A. "Recreation Carrying Capacity Reconsidered." *Jour. of Forestry.* **72** **(3)** (1974): 274-278.

Wagtendonk, J. W., and J. M. Benedict. "Travel Time Variation on Backcountry Trails." *Jour. of Leis.* Second Quarter (1980): 99-106.

Wang, B., and R. E. Manning. "Computer Simulation Modeling for Recreation Management: A Study on Carriage Road Use in Acadia National Park, Maine, USA." *Envir. Manag.* **23** **(2)** (1999): 193-203.

Watson, A. E., D. N. Cole, D. L. Turner, and P. S. Reynolds. "Wilderness Recreation Use Estimation: A Handbook of Methods and Systems." USDA Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-56, October 2000.

Williams, G. W. "Ecosystems and People: Social/Cultural Approaches and Methods." USDA Forest Service History, Office of Communications, Washington D. C., 1998 (http://demo.jorge.com/fs/social_papers/em_socialmethods_tucson.html.)